ELSEVIER

Global and Planetary Change 9 (1994) 165–167

GLOBAL AND PLANETARY CHANGE

Editorial

Simulating past climates. The data–model connection

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Received 10 October 1993; revised after revision 11 May 1994

The potential for large global climate changes associated with anthropogenic forcings has led to a variety of multidisciplinary, multinational research efforts aimed at developing the capacity to anticipate future climate changes and their impacts on the earth and its physical and biological systems. Numerical climate model development is central to many of these efforts and general circulation models (GCMs) are the primary numerical tool used to integrate the environmental changes that affect our climate, changes such as greenhouse gas and aerosol increases, ozone depletion, and deforestation. Simulating climates of the past is an important component in the ongoing effort to improve and evaluate GCM capabilities. Predictions of future changes gain credibility when models are robust enough to accurately simulate changes that have actually occurred in the past. Moreover, changes anticipated in the future are likely to exceed historical precedents whereas the geologic record contains examples of perturbations of the magnitude predicted for the next century.

Paleoclimate modeling, however, presents data and modeling groups with a variety of problems. One particularly difficult problem involves model boundary conditions, which are key parameters that must be specified for each model cell at the beginning of a simulation. Modern datasets are often inappropriate for initializing paleoclimate simulations, but control points from geologic data are limited. Thus we are faced with a conundrum. How do we generate a global scale network of values for key environmental boundary conditions at the appropriate grid scale, and who should do it? Our view is that data groups and modelers need to work closely together to resolve the problems involved in creating global scale data sets of key boundary conditions and on modeling key intervals of the past. Data groups are in the best position to generalize and then extrapolate and interpolate a gridded dataset from the limited control points, but that effort must be done in the context of the requirements and limitations of the models that will use the data. A separate but related problem involves evaluating model results. The result of a simulation is a set of predictions. Arrays of detailed, quantitative, site specific environmental information are needed to evaluate model results. Two types of paleodata are needed for modeling studies: the generalized global scale data sets for experimental boundary conditions, and detailed specific paleoclimate information for testing and evaluating model results.

The Pliocene Research, Interpretation, and Synoptic Mapping Project (PRISM) is focusing on documenting climates of the middle to late Pliocene. A primary goal of PRISM is to provide the modeling community with improved quantitative global paleoenvironmental information associated with warm climates of the Pliocene. In addition, the project provides a forum for data and modeling experts to work together in establishing what boundary condi-

SSDI 0921-8181(94)00006-Y

tions are needed, planning modeling experiments, and interpreting and evaluating model results. The modeling activity also helps test the consistency of different sets of paleoobservations, each of which has its own uncertainties.

The PRISM project involves the efforts of a number of national and international paleoclimate researchers and several modeling groups. In particular, during the past year, the Goddard Institute for Space Studies (GISS) has begun a program to simulate the middle Pliocene climate using the GISS general circulation model and PRISM data. The Pliocene interval selected for the first reconstruction and modeling experiments is centered in the middle part of the Gauss paleomagnetic chron (approximately 3.0 Ma in the time-scale of Berggren et al., 1985) where the evidence for significant global warming is clear: boreal forests extended to the margins of the Arctic Ocean (Matthews and Ovenden, 1990), North Atlantic and North Pacific high-latitude sea surface temperatures (SST) were significantly warmer than modern (Dowsett and Poore, 1991; Dowsett et al., 1993; Barron, 1992), and Antarctica was probably partially deglaciated (Webb and Harwood, 1991; Barrett et al., 1992).

Two papers in this volume report on an initial Northern Hemisphere paleoenvironmental reconstruction and a GCM simulation for the mid Gauss warm interval. The reconstruction and rationale for constructing preliminary boundary condition data sets at $8° \times 10°$ scale for Northern Hemisphere SST and vegetation, global sea ice, and continental ice are discussed by Dowsett et al. An initial modeling experiment using the GISS GCM with altered Northern Hemisphere boundary conditions is discussed by Chandler et al. The Pliocene boundary condition data are preliminary; North Atlantic Pliocene SST data reflect analyses from a number of deep sea cores and shallow marine sequences whereas North Pacific SST data and vegetation conditions in many regions are modified from modern values based on few control points. Despite these limitations the results of the initial experiment raise interesting questions and provide a promising first loop in the iterative process of model/data comparison; data collection → boundary condition adjustment → simulation → comparative analysis → question raising → data collection → etc.

The model results indicate that a ~30% change in meridional ocean heat transport may have been an important component of the climate change that resulted in Pliocene global warmth. This interpretation is supported by carbon isotopic data from deep-sea benthic foraminifers, which suggest formation of North Atlantic Deep water was increased during this same interval (Raymo et al., 1992). The continental temperature patterns produced by the Pliocene simulation agree fairly well with available evidence from individual palynological records. This is especially true in the circum-North Atlantic region, which is expected because the area is strongly influenced by the warm North Atlantic SSTs. Alternatively the Pliocene simulation is not as effective at simulating seasonal moisture conditions over the continents. For example, the model predicts lower effective moisture in western North America, but geologic records from that area indicate wetter conditions during this time. It is not surprising that the GCM has difficulty in reproducing regional hydrologic details given the complexities of scale associated with parameterizing clouds, convection, vegetation, and ground hydrology. In addition, post Pliocene mountain-building in western North America and limited control on North Pacific SST compound the difficulty of simulating the climate of this region.

Identifying model/data contrasts might be considered the main objective of any comparison project. Successful comparisons, while increasing our confidence in the basic approach, probably occur coincidentally in some cases and such errors would be quite difficult to identify. However, mismatches that appear between data interpretations and model results offer unequivocal evidence that either model, data, or both are inaccurate for a given region and a given climate parameter. This, in turn, allows us to focus resources and efforts on areas that are likely to proffer the most gain. Moreover, subsequent iterations, based on new treatments of the data or GCM, test the veracity of previous conclusions.

The PRISM reconstruction and GISS GCM simulation reported in this issue are a first step in the interactive process of data collection, analysis, model experimentation and data/model comparison; the gridded, boundary condition data sets are currently being refined, updated, and extended into the Southern Hemisphere. Additional modeling and sensitivity experiments involving the new data sets and three different GCMs are in progress. Close cooperation between data and modeling groups can achieve an overall better understanding of the data, data collection strategies, GCMs, modeling techniques, and ultimately, the Earth's climate.

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